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ontario hydro
research division

To Mr. R.A. Wright
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Hydraulic Plant Equipment
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Attn: Mr. A. Dmochowski

WESTERN REGION MACHINE SHOP
SOILS INVESTIGATION AND CONSTRUCTION RECOMMENDATIONS

J.B. Enright

INTRODUCTION

At the request of the Hydraulic Plant Equipment Department, a series of soil investigations have been performed along the SAB GS intake canal. Data from these investigations was required to assist in selecting a site for the Western Region Machine Shop building and to provide engineering data for building design on the selected site.

The investigation was carried out in four stages. Stage 1 provided data on five possible sites to aid site selection. Stage 2 provided additional site selection information for two sites near the PGS. Stages 1 and 2 are summarized in Ontario Hydro Report 86-197-K. Stage 3 provided data to aid in locating the building on the chosen site and is summarized in Ontario Hydro Report 86-242-K. Stage 4, the most recent investigation, will provide soil bearing pressures, settlement data and construction recommendations, and is contained in this report.

FIELD AND LABORATORY WORK

Stage 4 consisted of performing three engineering boreholes using hollow stem and flight augers and excavating two test pits in the locations shown on Figure 1. Boreholes 40, 41 and 42 were augered to refusal with sampling every 1.5 metres to provide soil samples for laboratory testing. All boreholes were backfilled upon completion. Test pits 1 and 2 were excavated to investigate a suspected layer of rockfill located 0.5 metres beneath the ground surface.

Granular soils were generally sampled using the 51 mm OD split spoon sampler advanced by the Standard Penetration Test Method. This test yields the "N" value for the soils being sampled. Cohesive soils were generally sampled by pushing a thin wall 51 mm OD Shelby tube sampler.

The laboratory testing included determination of moisture content, bulk density, shear strength, consolidation testing and soil classification.

SUBSOIL CONDITIONS

In general, the site is covered by fill which consists predominantly of silt and extends from ground level to an average depth of 3.3 metres below ground level. This silt fill is reddish brown, has quite variable density and moisture content, and is compressible. A layer of limestone crusher rock exists within the fill between the depths of 0.4 and 1.5 metres below ground level. This layer appears to be continuous across the site as it was observed in virtually all of the boreholes. Beneath the fill is a stiff grey clayey silt which is followed by a unit of dense reddish brown silt, a unit of dense brown clayey silt, a unit of silt till and bedrock. The bedrock is limestone. Figure 2 shows a cross section through the site and the expected succession of soil units.

The geotechnical logs for boreholes 40, 41 and 42 are included in this report as Figures 3, 4 and 5. In drilling these boreholes, the auger was observed to grind between 0.6 and 1.35 metres below ground level. Test pit 1 was excavated adjacent to borehole 40 to examine the cause of the grinding in the location shown on Figure 1. This test pit revealed the presence of a layer of limestone blast rock in the surficial fill. The rock was observed to consist of boulder sized pieces ranging in size from 10 to 50 cm in diameter and averaging 25 cm in diameter. The geotechnical log for test pit 1 is included in this report as Figure 6.

The subsurface conditions were found to be generally similar to the findings of previous reports with one further exception. In excavating test pit 2, an old road bed of finely crushed rock was encountered at a depth of 0.55 metres below ground level. The exact location and direction of the road are not known. In an earlier phase of this investigation, boreholes 30 and 30A met auger refusal in this location at depths of 1.55 and 1.10 metres respectively. This refusal was previously attributed to possible bedrock but is now known to be due to the old road bed and thus the true bedrock elevation in this location is not known. Figure 7 and 8 show revised cross section views along the north and south limits of the site. These cross sections show the inferred location of the bedrock obtained from previous investigations and also show the estimated position of the bedrock beneath the location of the old road bed. These cross sections show that the depth to bedrock across the site ranges between 8 metres and 11 metres and on average is approximately 9.7 metres.

The ground water levels were observed in each borehole on completion of drilling and again after some time had passed. These observations are summarized on the borehole profiles and indicate that the equilibrium water table is approximately 2.5 metres above the bedrock. No caving soils were observed in boreholes 40, 41 and 42.

A summary of the physical properties of each soil unit is presented in Table I. This table shows the order in which the soil types are found in-situ and states average, maximum and minimum values of thickness, water content, natural density, "N" value, and shear strength. In general, this

table shows that the water content and density of the silt fill is quite variable while the water content and density of the remaining units shows small amounts of variation. Generally, the strength of the soil units increases with depth, however, the silt fill, grey clayey silt and silt till show a wide range of strengths which are reflected in the laboratory shear strengths and "N" values.

A summary of the samples used for consolidation testing is presented in Table II. This table lists the borehole from which the samples were obtained, the depth of the samples relative to the ground surface, a brief description of the samples and the preconsolidation pressures that were determined for the samples. The preconsolidation pressures were determined in the lab from the results of the consolidation testing performed on soil samples obtained from the anticipated foundation level. The preconsolidation pressures, as determined in the lab, for the grey to brown clayey silt are 230 and 340 kPa and the preconsolidation pressures for the reddish brown silt are 140 and 285 kPa. The void ratio versus log pressure curves for each of the four consolidation samples are included in this report as Figures 9, 10, 11 and 12. Settlement calculations were performed using as input the reported preconsolidation pressures and soil properties summarized in Tables I and II and the loadings and other parameters that are listed in Table III.

FLOOR SLAB DESIGN

The overlying fill is silt, which is variable in density and moisture content, contains compressible zones and a rockfill layer. Under the proposed floor loading of 50 kPa, elastic settlement is expected in the silt fill. With the base of the floor slab located at 185.0 metres, a total bearing pressure of 50 kPa, and an assumed elastic modulus of 11 MPa for the silt fill, the expected total elastic settlement is estimated to be approximately 3.8 cm (1.5 inches). In addition, the total elastic settlement will not be uniform. Up to 3.8 cm (1.5 inches) of differential settlement can be expected across the length of the building. The existence of an old road bed beneath the western portion of the site will likely limit the amount of settlement in this location, while the greatest amount of settlement is expected to occur on the eastern portion of the site.

The amount of settlement that occurs in the silt fill may be reduced if the bearing capacity of the silt fill is improved by either surcharging or compaction. Surcharging the site would require enough fill to cover the site to a depth of 2.5 metres and would be practical only if sufficient time and fill material are available. Alternatively, the use of dynamic compaction may be considered but the use of this method would be dependent on testing conducted on site to determine the amount of improvement of bearing capacity which could be achieved. It is suggested that compaction to 95% of Standard Proctor Density will sufficiently increase bearing capacity and achieve acceptable amounts of settlement.

The expected maximum amounts of settlement, if they occur, may cause some cracking of the floor slab. In order to minimize cracking of the concrete floor slab, two sets of construction joints are suggested. It is

recommended that construction joints be included in the floor slab at about 6 metre spacings and between the floor slab and the building wall. These two construction joints will give the concrete floor a limited amount of flexibility and will separate the floor slab from the building structure and thus will minimize cracking due to settlement.

Since the overlying fill is predominantly silt, it is recommended that precautions be included in the design to limit the occurrence of frost heave.

FOUNDATION DESIGN

Footing loadings of 200 kPa were previously recommended based on the shear strength of the soil. It is now known that this bearing pressure exceeds the preconsolidation pressure of the natural soil and would lead to unacceptable settlement. A consolidation settlement analysis was performed which determined that settlements of up to 6.35 cm (2.5 inches) would be expected to occur in the reddish brown silt if the crane foundation were established on soil. A summary of the parameters used in the consolidation settlement analysis is included in this report as Table III, and the void ratio versus log pressure curves used in the analysis are included in this report as Figures 9, 10, 11 and 12.

Bearing pressures of 100 kPa are now recommended for lightly loaded footings. These loads are based on restricting settlements to less than 2.5 cm (1 inch), which will occur in the reddish brown silt. These footing loads may be safely established on the clayey silt beneath the silt fill, however, field inspection is required to confirm suitable bearing capacity before pouring the footings. It is recommended that the depth at which the lightly loaded footings are established be a minimum of 1.2 metres (4 feet) beneath ground level to provide some protection against the effects of frost heave.

For heavily loaded footings, such as those used by the crane, a maximum bearing pressure of 100 kPa results in the size of footings becoming excessive (eg. 27 square metres) such that interactions between the building and crane footings could not be avoided. Therefore, it is recommended that the crane foundations be established on bedrock using either caissons or piles. The bedrock is limestone and the depth to bedrock across the site ranges from 8 metres to 11 metres and averages 9.7 metres.

Caissons founded on bedrock may be designed for an allowable bearing capacity of 1900 kPa (20 TSF). These caissons must be thoroughly cleaned out and inspected by a geotechnical engineer to verify suitable bearing rock prior to placing the concrete.

For HP 310 X 110 piles driven to bedrock, the allowable load per pile is 1000 kN. All piles should be driven to refusal on bedrock which will be defined by the designers, with assistance from the author, prior to tendering the piling contract. Pile driving should be inspected to ensure proper installation.

The layer of blast rock in the silt fill will cause some difficulty in augering the caissons and in driving the piles. The presence of this layer should be accounted for in estimating footing costs and in the contractor's construction procedure.

BUILDING DESIGN

To minimize cracking of the concrete floor slab, two sets of construction joints have been suggested. Construction joints have been recommended in the floor slab and also between the floor slab and the building wall. These two construction joints will give the concrete floor some flexibility and will separate the floor slab from the building structure and thus will reduce cracking caused by settlement.

It is also suggested that the design of the floor slab include measures to minimize frost heave which may occur in the silt fill.

CONSTRUCTION CONSIDERATIONS

No caving soils were observed on the site and the water table is estimated to be approximately 2.5 meters above the surface of the bedrock. It should be noted that water levels were measured shortly after the completion of drilling and thus sufficient time had not elapsed to re-establish the equilibrium level of the watertable.

The blast rock layer that was confirmed in the silt fill and the old road bed that was observed in test pit 2 should be noted when planning the construction of the foundations so that suitable measures may be taken.

CONCLUSIONS

The subsurface soil conditions have been documented and summarized in this report. A layer of blast rock was confirmed in the surficial silt fill which will cause some difficulty in foundation construction. No problems are anticipated with wet or caving soil during construction. The available bearing capacity for the floor loads has been reported and recommendations are made for increasing soil bearing capacity. Bearing pressures and recommendations for foundation location are included for lightly loaded foundations. Recommendations are made to establish heavily loaded foundations on piles or caissons bearing on bedrock. Suggestions for inclusion in the building design are made and construction

considerations are summarized. All foundation construction should be inspected by a Geotechnical Engineer.

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TABLE I

Summary of Soil Properties - Western Region Machine Shop

Soil Property	Silt Fill	Grey to Brown Clayey Silt	Reddish Brown Silt	Brown Clayey Silt	Brown Silt Till
Thickness, m					
Range (min-max)	2.50-4.04	0-3.05	2.36-5.11	0-1.45	0-2.6
Average	3.28	1.66	3.28	0.39	1.09
Water Content %					
Range (min-max)	14.2-29.6	19.8-26.4	18.8-22.8	19.8-23.2	8.1-13.1
Average	17.2	21.6	20.6	21.5	11.2
Natural Density, kg/m^3					
Range (min-max)	1976-2218	1968-2055	1999-2083	2058-2071	2203-2395
Average	2112	2014	2049	2071	2266
Shear Strength, kPa					
Range (min-max)	49-170	66-137	77-97	121-133	116-271
Average	83	102	88	127	194
"N" Value Per 0.3 m					
Range (min-max)	16-50	16-17	63-68	25-25	32-95
Average	31	16	65	25	65

NOTE: Soil types are presented from left to right as they would be found in situ from ground surface downward, followed by bedrock.

TABLE II

Summary of Consolidation Testing - Western Region Machine Shop

Borehole	Depth of Sample (m)	Description of Sample	Preconsolidation Pressure (kPa)
40	3.05 - 3.50	grey to brown clayey silt	340
40	4.57 - 5.02	reddish brown silt	285
41	4.57 - 5.02	reddish brown silt	140
42	3.05 - 3.50	grey to brown clayey silt	230

TABLE III

Summary of Consolidation Testing Parameters - Western Region Machine Shop

Module Thickness: Average thickness of each soil unit as reported in Table I.

Assumed Maximum Load on Crane Column: 2700 kN (compression).

Assumed Floor Loading: 4900 kg/m^2 = 48.1 kPa.

Assumed Elastic Modulus for Silt Fill: E = 11,000 kPa = 11 MPa

Floor Slab Elevation at Base: 185 m

Average Cut from Silt Fill to Reach Floor Slab Elevation of 185.0 m = 0.5 m.

Soil Properties Used are Averages Obtained from Table I.

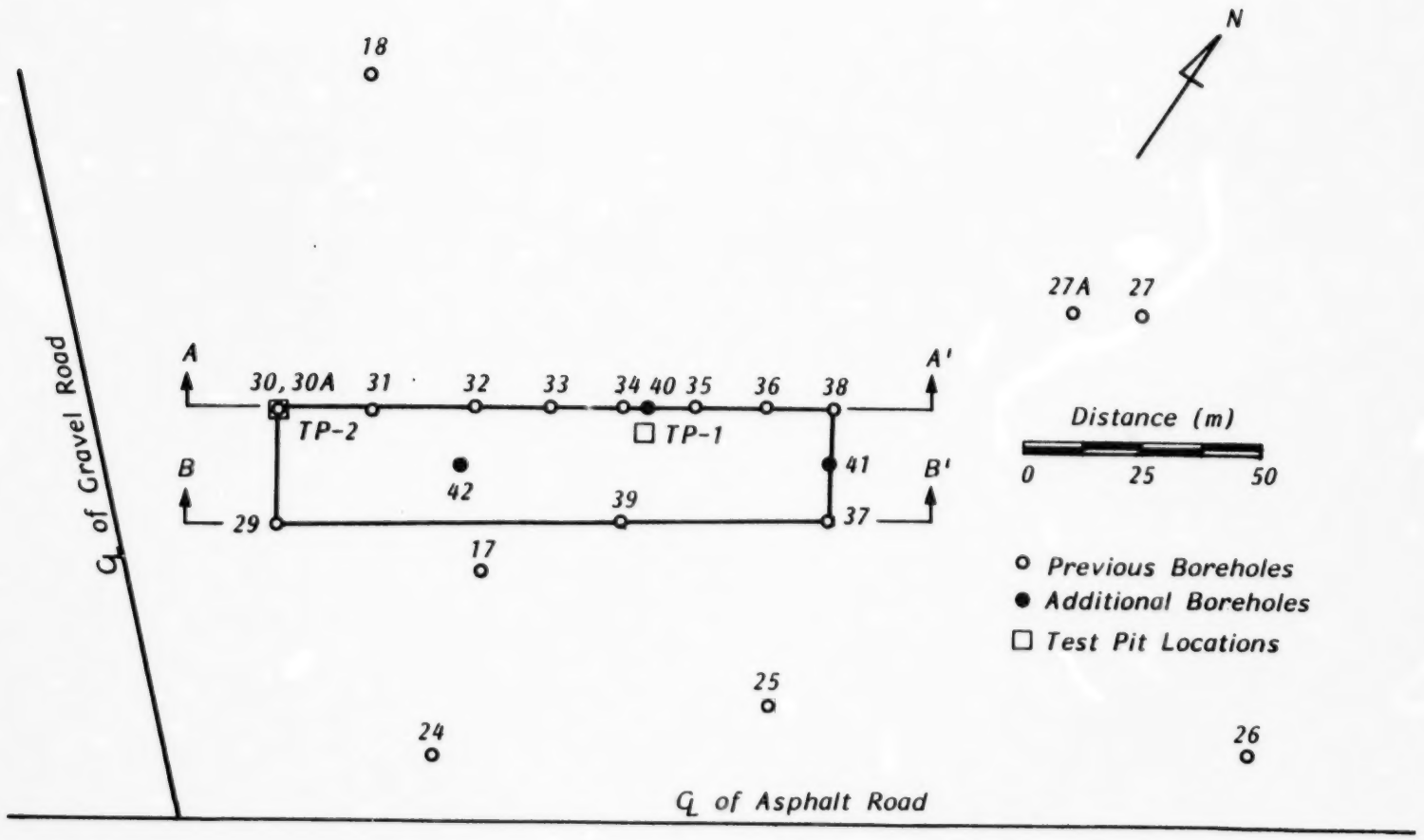

FIGURE 1

WESTERN REGION MACHINE SHOP
LOCATIONS OF ADDITIONAL BOREHOLES

172166-RD

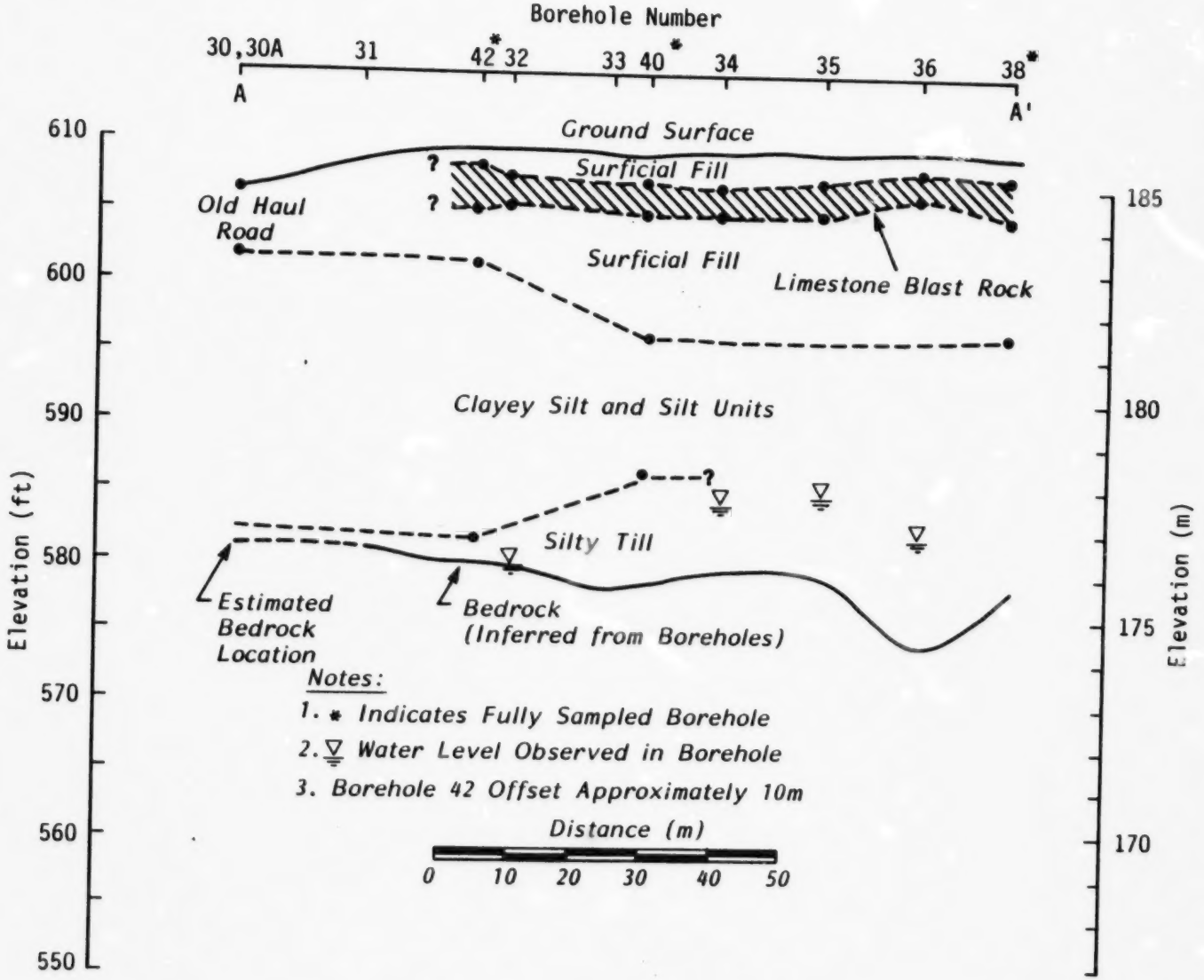

FIGURE 2

SECTION A-A', INTERPRETED SOIL AND ROCK PROFILE

173119 RD

PROJECT WESTERN REGION MACHINE SHOP — HOLE TYPE FLIGHT AUGER — OBSERVER D.W.

LOCATION SEE FIGURE 1 — HOLE SIZE 4 1/2" — COMPILED J.B.

DIP — DRILLED AUG.26/86 — CHECKED

DATUM FROM SITE PLAN — BEARING — DRAWN OCT.13/86 — APPROVED

DWG.NO. D.D.33111E

BORING DATA						BORING LOG		WATER INF.		FIELD TESTS		LABORATORY TESTS					
SCALE-METRES	ELEV / DEPTH	(1) SAMPLE NO	(2) SAMPLE TYPE	(3) 'N' VALUE per 0.3m / RQD-%	(4) WATER LEVEL and CAVING W.R	(5) DESCRIPTION	(6) REMARKS	(7) OBSERVATION WELL DATA	(8) 'k' soil/rock cm/s / WATER PRESS. TEST	(9) SPECIAL TESTS TYPE	(9) SPECIAL TESTS RESULTS	NATURAL DENSITY kg/m³	MOISTURE CONTENT - %	(10) SHEAR STRENGTH kPa TYPE	(10) SHEAR STRENGTH kPa RESULTS	(11) SPECIAL TESTS TYPE	(11) SPECIAL TESTS RESULTS
1						SILT, Grey Brown, with a trace of clay and fine sand, very dense, damp. Fill material.											
2		1		PUSH		Layer of excavated limestone crusher rock from 0.60m to 1.30m.						2109	17.9	u/c	71		
3		2		PUSH													
4						4.04m											
5		3		PUSH		SILT, reddish brown, with a trace to little clay and fine sand, and a few dry silt pockets, dense, damp.						2047	20.0	u/c	221		
6		4		PUSH								1999	21.7	u/c	99		
7					▽	7.00m											
8		5		PUSH		SILT TILL, grey brown, very dense, damp.						2203	11.9	u/c	116		
9		6		95		9.60m											
10						END OF HOLE - Bedrock (Inferred)												
						Water level at 8.80 metres below ground level at completion of drilling.											
						Water level at 7.50 metres after 3 hours.											

GEOTECHNICAL DATA SHEET

hole no 40 — Fig 3

sheet 1 of 1

200679 RD 00 Bap

86-318

PROJECT WESTERN REGION MACHINE SHOP — HOLE TYPE FLIGHT AUGER — OBSERVER D.W.

LOCATION SEE FIGURE 1 — HOLE SIZE 4 1/2" — COMPILED J.B.

DIP — DRILLED AUG.25/86 — CHECKED

DATUM FROM SITE PLAN — BEARING — DRAWN OCT.14/86 — APPROVED

DWG.NO. D.D.33111E

BORING DATA						BORING LOG	WATER INF.	FIELD TESTS		LABORATORY TESTS					
SCALE - METRES	ELEV / DEPTH	(1) SAMPLE NO	(2) SAMPLE TYPE	(3) 'N' VALUE per 0.3m / ROD-%	(4) WATER LEVEL and CAVING / W.R.	(5) DESCRIPTION / (6) REMARKS	(7) OBSERVATION WELL DATA	(8) 'k' soil/rock cm/s WATER PRESS TEST	(9) SPECIAL TESTS TYPE	(9) SPECIAL TESTS RESULTS	NATURAL DENSITY kg/m³	MOISTURE CONTENT - %	(10) SHEAR STRENGTH kPa TYPE	(10) SHEAR STRENGTH kPa RESULTS	(11) SPECIAL TESTS TYPE	(11) SPECIAL TESTS RESULTS
1						SILT with a trace of clay and fine sand, reddish brown, compact, fill material.										
2		1	⊠	27		Layer of excavated limestone crusher rock from 0.60m to 1.35m.					2168	14.4	u/c	170		
3		2	■	PUSH							2070	17.0	u/c	126		
4						4.04m										
5		3	■	PUSH		CLAYEY SILT, with a trace of fine sand, very stiff, damp.					2023	19.0	u/c	137		
6		4	■	PUSH		5.56m SILT, reddish brown, with a trace of fine sand and clay, and a few clay layers, very stiff, damp.					2034	20.8	u/c	91		
7																
8		5	■	PUSH								19.1				
9						8.61m SILT TILL, reddish brown, with a little fine sand and gravel, damp, dense.										
10		6	⊠	32	▽						2242	13.1	u/c	271		
						10.21m END OF HOLE - Bedrock (Inferred)										
						Hole was dry after completion of drilling.										
						Water level at 10.0 metres after 2 hours.										

GEOTECHNICAL DATA SHEET

hole no. 41 — Fig 4

sheet 1 of 1

cdg no. 200678 RD

86-318

PROJECT WESTERN REGION MACHINE SHOP
LOCATION SEE FIGURE 1
DATUM FROM SITE PLAN D.O. 33111E
DIP
BEARING

HOLE TYPE FLIGHT AUGER
HOLE SIZE 4 1/2"
DRILLED AUG.26/86
DRAWN OCT.14/86

OBSERVER D.W.
COMPILED J.B.
CHECKED
APPROVED

BORING DATA						BORING LOG	WATER INF.		FIELD TESTS		LABORATORY TESTS					
SCALE - METRES	ELEV / DEPTH	(1) SAMPLE NO	(2) SAMPLE TYPE	(3) 'N' VALUE per 0.3m / RQD - %	(4) WATER LEVEL and CAVING W.R	(5) DESCRIPTION / (6) REMARKS	(7) OBSERVATION WELL DATA	(8) 'k' soil/rock cm/s / WATER PRESS TEST	(9) SPECIAL TESTS TYPE	(9) SPECIAL TESTS RESULTS	NATURAL DENSITY kg/m³	MOISTURE CONTENT - %	(10) SHEAR STRENGTH kPa TYPE	(10) SHEAR STRENGTH kPa RESULTS	(11) SPECIAL TESTS TYPE	(11) SPECIAL TESTS RESULTS
1						SILT, reddish brown, trace of clay, very dense, damp. Fill material.										
2		1	⊠	50		Layer of excavated limestone crusher rock from 0.6m to 1.30m.					2157	14.2				
						2.50m										
3		2	■	PUSH		SILT, grey brown, with some clay and trace of fine to medium sand, dense, damp.					2037	20.3	u/c	66		
4						4.04m										
5		3	■	PUSH		SILT, reddish brown, with a trace of clay, moist to wet, dense.					2036	20.1	u/c	107		
6		4A	■	PUSH							2021	21.8	u/c	82		
		4B	⊠	87								22.8				
7						7.16m										
8		5	⊠	25		CLAYEY SILT, grey brown, with a trace of fine to medium sand and fine gravel, very dense, damp.					2058	23.2	u/c	133		
						8.61m										
9		6	⊠	36	▽	SILT TILL, reddish brown, very dense damp					2223	11.5				
						9.30m										
10						END OF HOLE - Bedrock (Inferred)											
						Water level at completion of drilling was 9 metres below ground level.										

GEOTECHNICAL DATA SHEET

hole no 42 | Fig 5

sheet 1 of 1

dwg no 200680 RD

86-318

PROJECT WESTERN REGION MACHINE SHOP
LOCATION SEE FIGURE 1
DATUM FROM SITE PLAN DWG.NO. D.O. 33111E

HOLE TYPE TEST PIT
HOLE SIZE
DIP
EXCAVATED AUG.26/86
BEARING
DRAWN OCT.14/86

OBSERVER D.W.
COMPILED J.B.
CHECKED
APPROVED

BORING DATA						BORING LOG		WATER INF.	FIELD TESTS		LABORATORY TESTS					
SCALE-METRES	ELEV / DEPTH	(1) SAMPLE NO	(2) SAMPLE TYPE	(3) 'N' VALUE per 0.3m / ROD-%	(4) WATER LEVEL and CAVING W.R.	(5) DESCRIPTION	(6) REMARKS	(7) OBSERVATION WELL DATA	(8) 'k' soil/rock cm/s WATER PRESS TEST	(9) SPECIAL TESTS TYPE	(9) SPECIAL TESTS RESULTS	NATURAL DENSITY kg/m³	MOISTURE CONTENT - %	(10) SHEAR STRENGTH kPa TYPE	(10) SHEAR STRENGTH kPa RESULTS	(11) SPECIAL TESTS TYPE	(11) SPECIAL TESTS RESULTS
1						SILT FILL, reddish brown											
						Limestone crusher rock											
						Limestone blast rock											
2																	
3						Note: Limestone crusher rock and blast rock part of an old haulage road.											
4						Photograph: Taken and available from Civil Research.											
5																	

dwg no 200677 RD

GEOTECHNICAL DATA SHEET

hole no Test Pit #1 | Fig 6

sheet 1 of 1

86-318

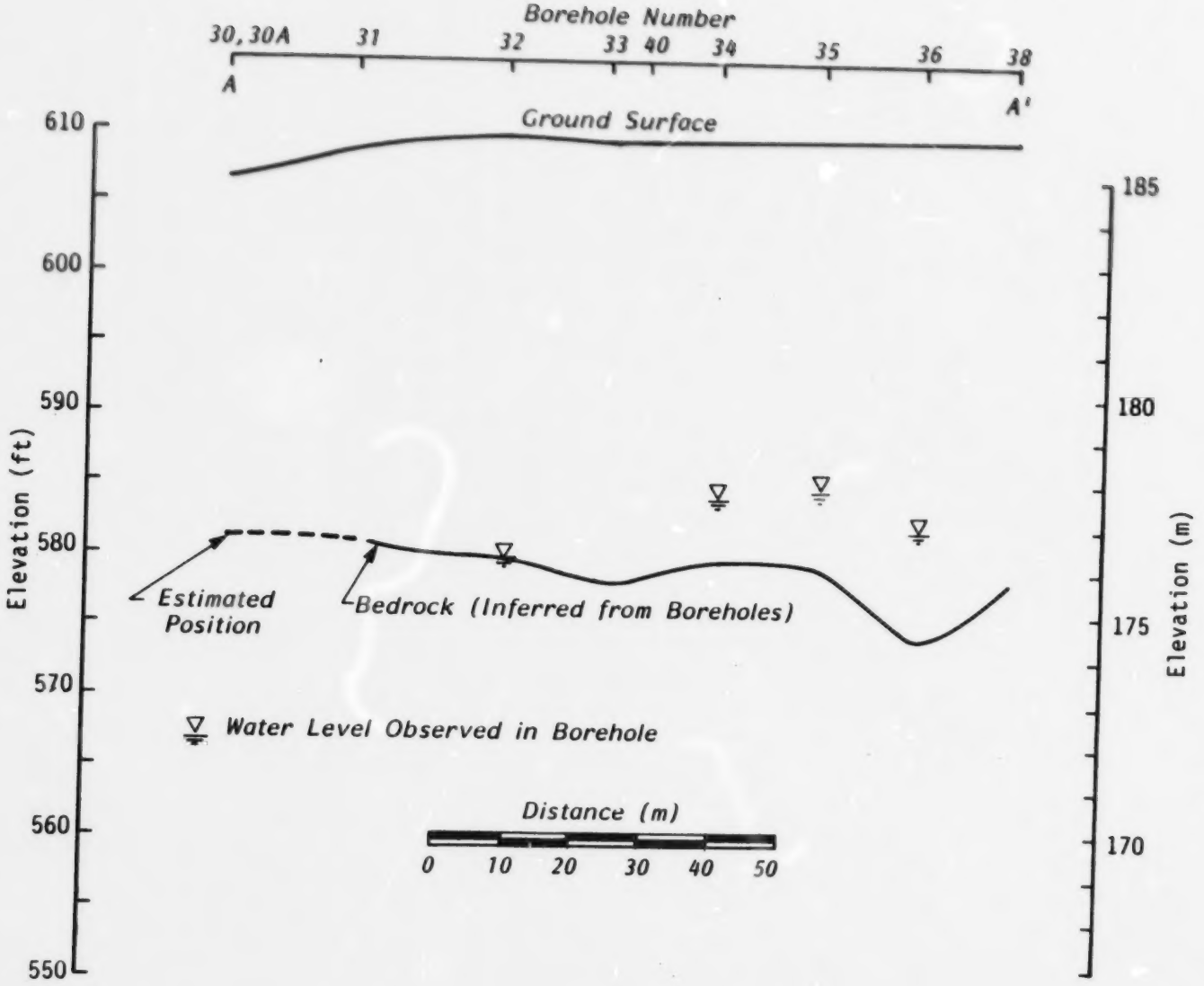

FIGURE 7
SECTION A-A', INTERPRETED BEDROCK PROFILE

172164-RD

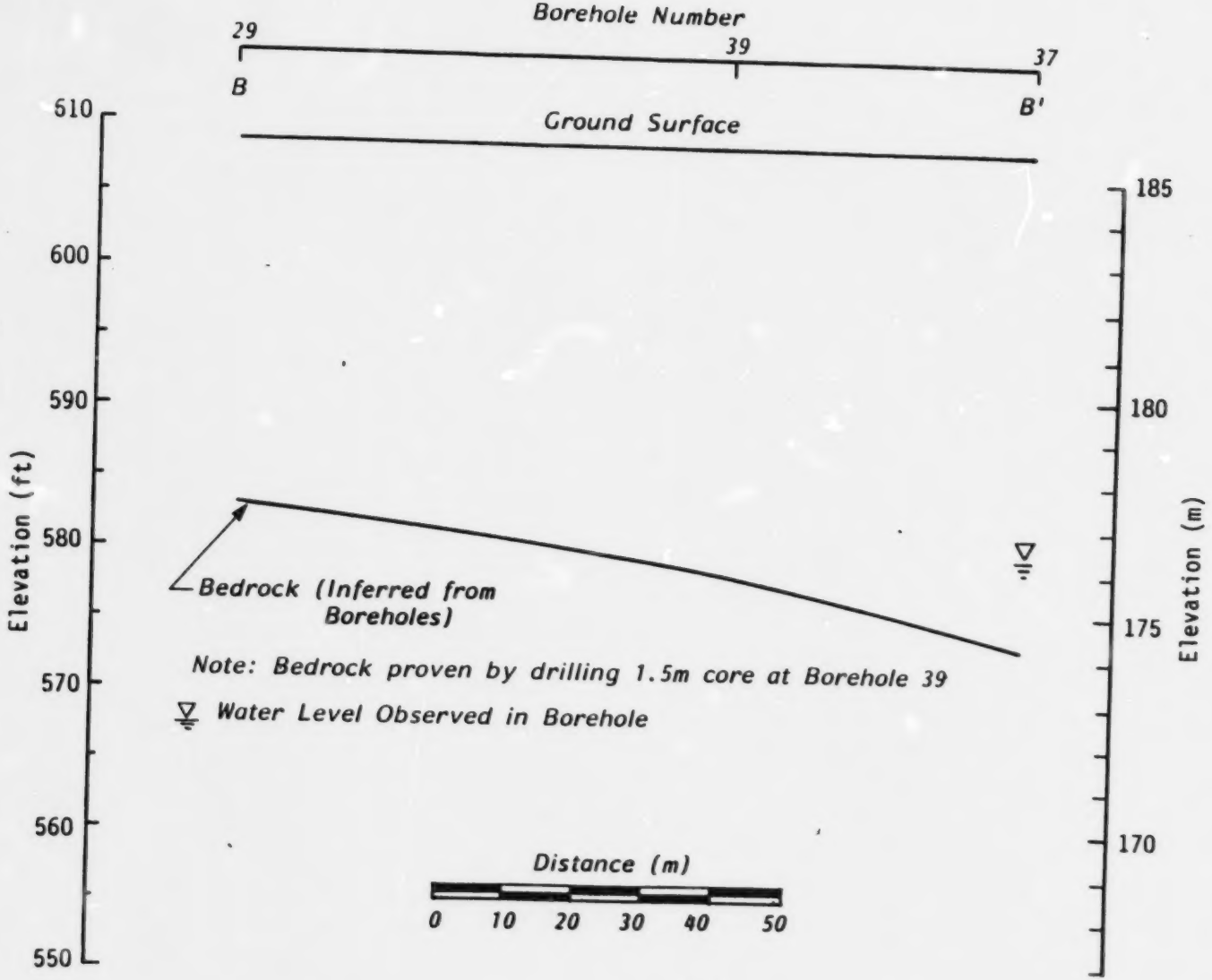

FIGURE 8

SECTION B-B' - INTERPRETED BEDROCK PROFILE

172165-RD

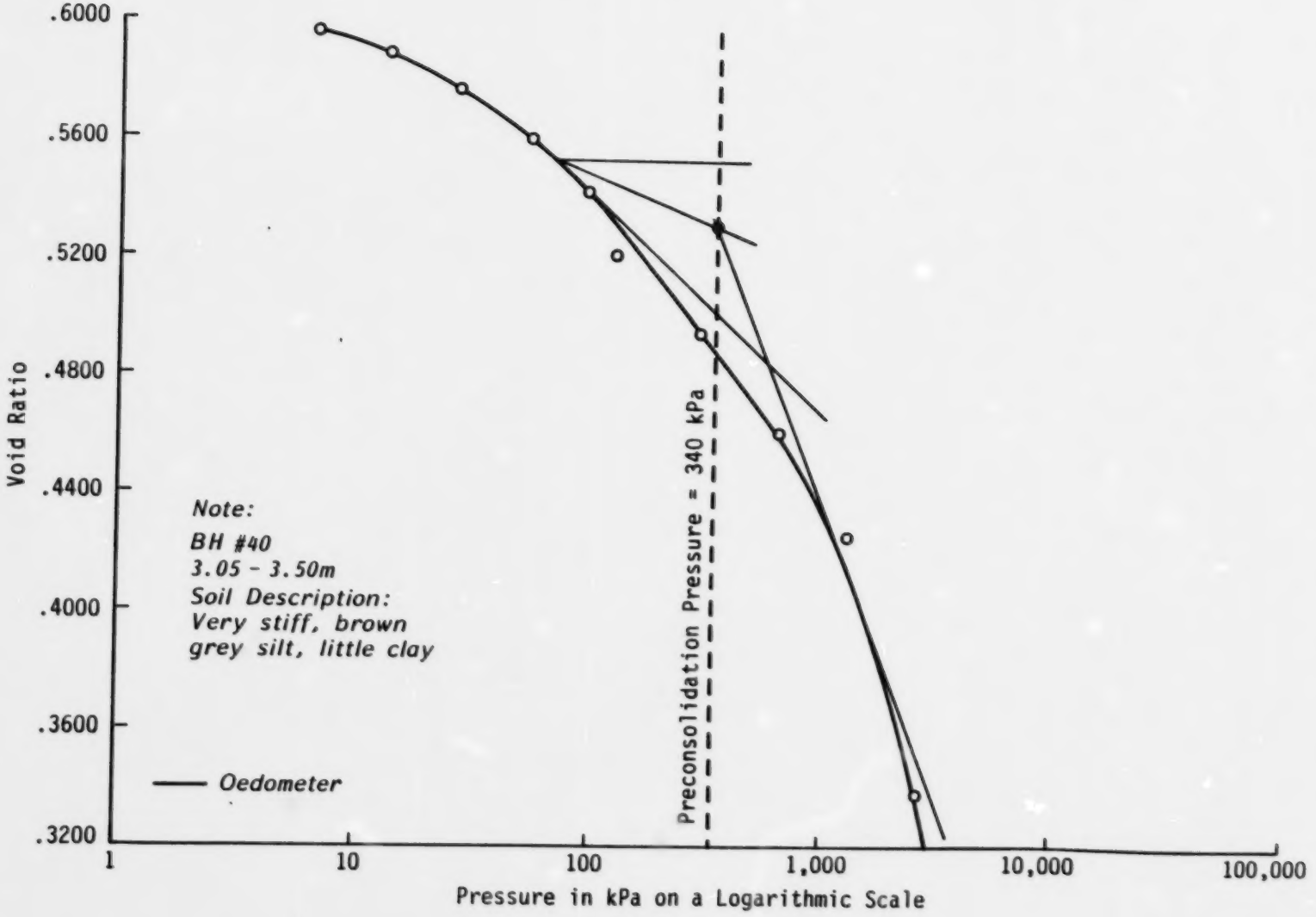

FIGURE 9

WESTERN REGION MACHINE SHOP CONSOLIDATION TEST

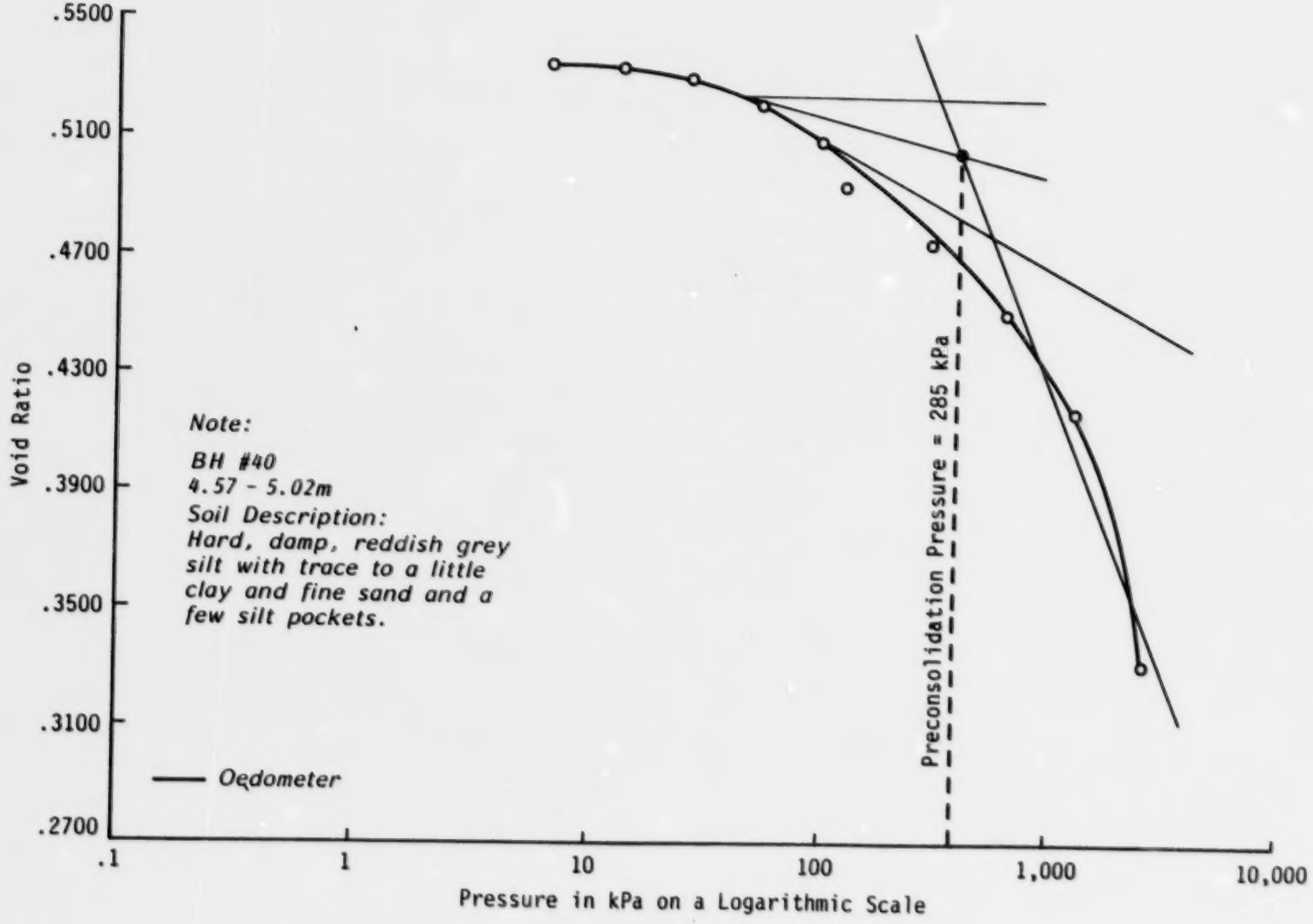

FIGURE 10

WESTERN REGION MACHINE SHOP CONSOLIDATION TEST

173121 RD

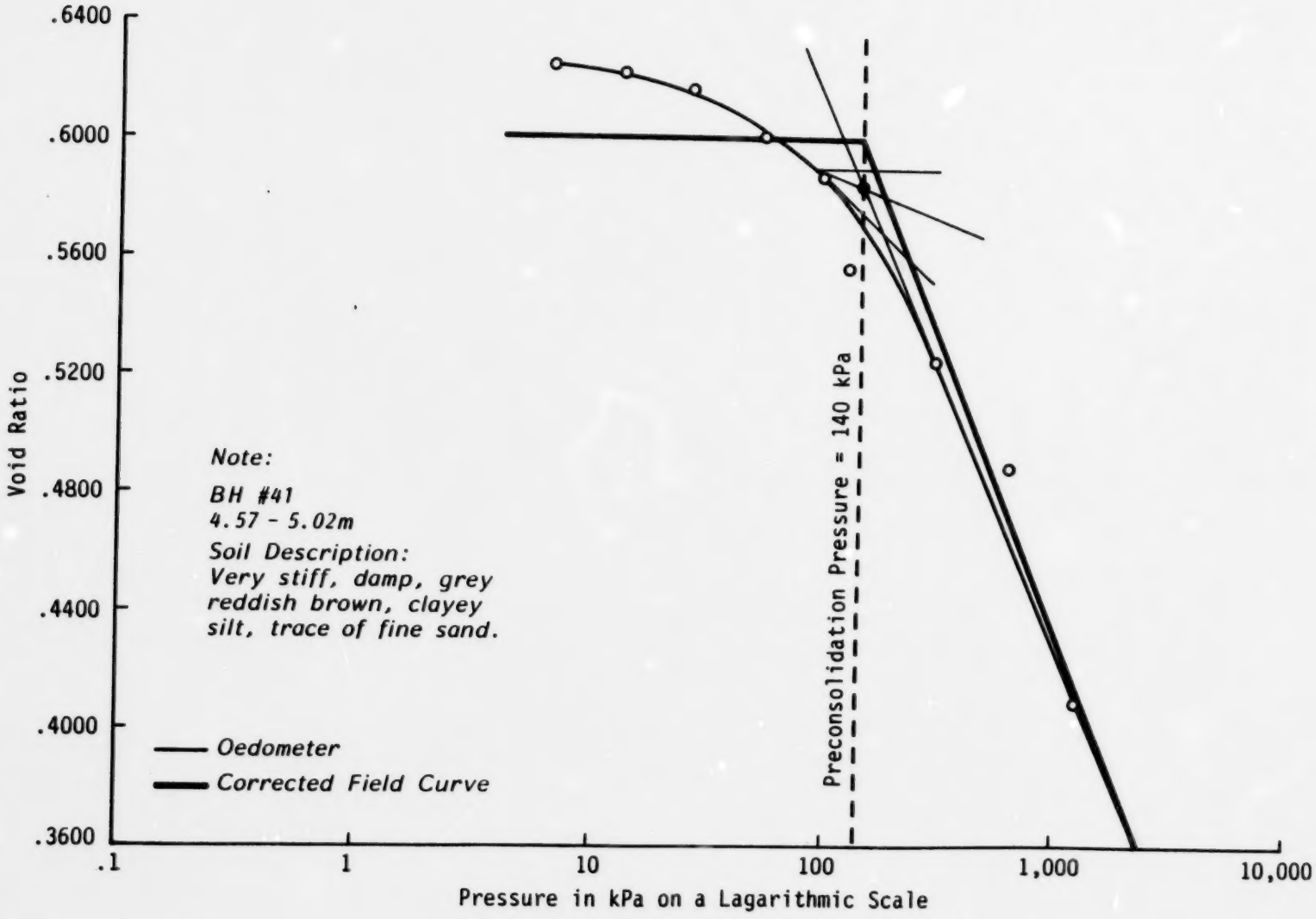

FIGURE 11

WESTERN REGION MACHINE SHOP CONSOLIDATION TEST

173122 RD

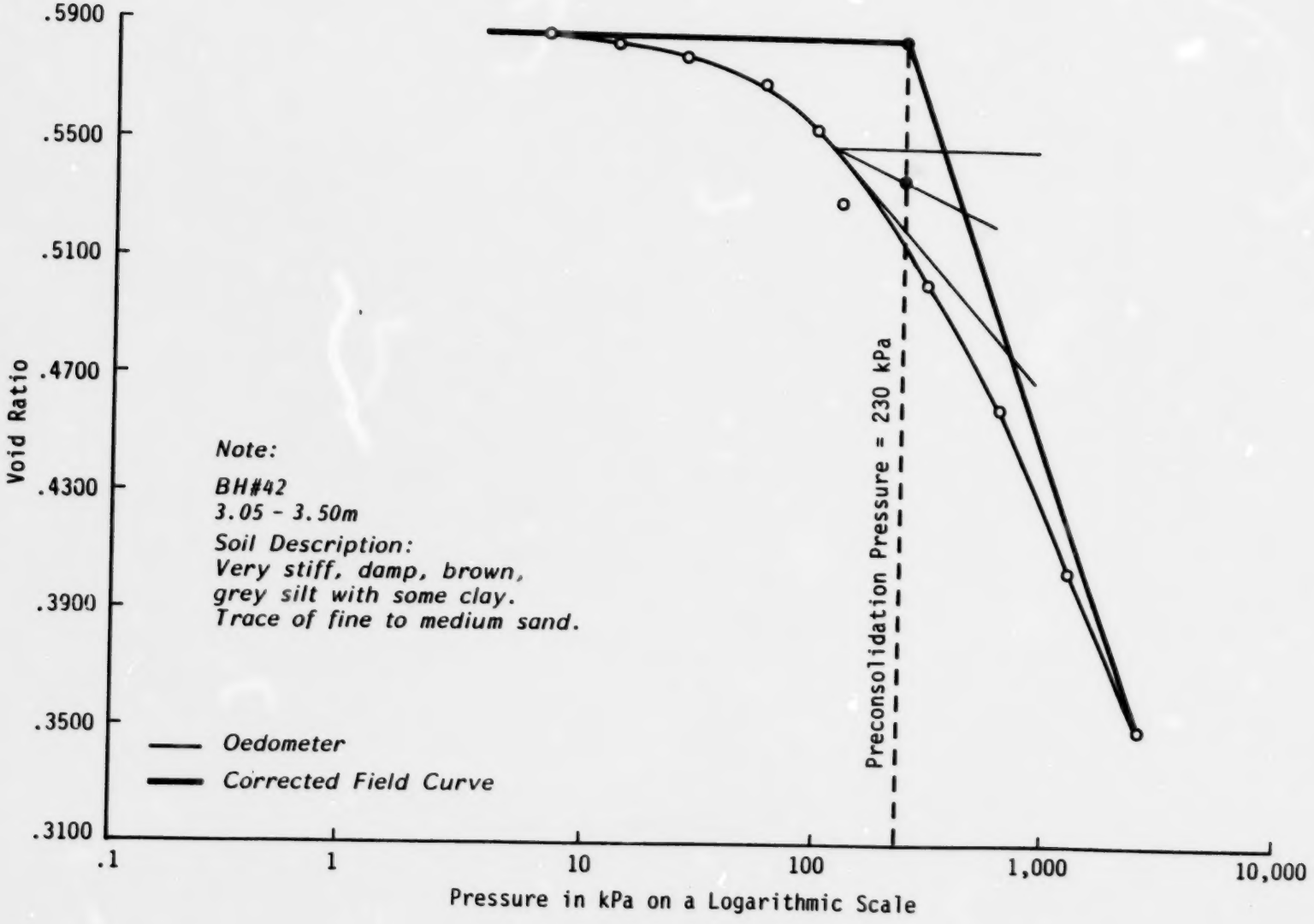

FIGURE 12

WESTERN REGION MACHINE SHOP CONSOLIDATION TEST

173123 RD